THE GRANITIC ROCKS OF THE PIKES PEAK QUADRANGLE[1]

GENERAL RELATIONS

FEW natural features in the west are better known by name and form than Pikes Peak, which has served so often as a goal for the pioneer and traveler or as a fitting subject for the photographer and artist. Its prominence arises from its position as the landmark first seen by the traveler moving westward, and from the abruptness with which it rises 8000 feet above the plateau at Colorado Springs.

Moreover, the rapid developments in mining at Cripple Creek and the papers[2] that have recently appeared on the subject have increased the interest in the area and have directed thought to its geology.

In the present paper it is proposed to give a summary of the results obtained from a field and detailed laboratory study of the

[1] Published by permission of the Director of the U. S. Geological Survey.

The field work for the present paper was carried on by the writer while a field assistant in the party of Mr. Whitman Cross who directed the work and suggested the problems to be studied. Many of the specimens were collected by Mr. Cross, and his field notes have been used freely. For the constant willingness to give assistance and the freedom in the use of notes, the writer wishes to express his gratitude to Mr. Cross, who furnished the opportunity to study so extensive an area.

[2] WHITMAN CROSS: Intrusive Sandstone Dikes in Granite, Bull. Geol. Soc. of Am., Vol. V., 1894, pp. 225–230; Geology of the Cripple Creek Gold Mining District; Proc. Colo. Sci. Soc., June 4, 1894.

R. A. F. PENROSE, JR.: The Ore Deposits of Cripple Creek, Colo. *Ibid.*

E. B. MATHEWS: The Granites of the Pikes Peak Area, Bull. Geol. Soc of Am., Vol. VI, 1894, pp. 471–473.

WHITMAN CROSS and R. A. F. PENROSE, JR.: Geology and Mining Industries of the Cripple Creek District, Colo. Part I, General Geology, WHITMAN CROSS; Part II, Mining Geology, R. A. F. PENROSE, JR. Sixteenth Ann. Rept. Dir. U. S. Geol. Surv., II, Washington, 1895, pp. 13–217.

W. O. CROSBY: The Great Fault and accompanying Sandstone Dikes of Ute Pass, Colorado, Science, new series, Vol. V, 1897, pp. 604–607. Archean Cambrian Contact near Manitou, Colorado, Bull. Geol. Soc. of Am., Vol. X, 1899, pp. 141–164.

granular igneous rocks comprising the summit of Pikes Peak, and the area to the west of it, included within the Pikes Peak quadrangle of the Geologic Atlas of the United States. The field observations were made during the seasons of 1893 and 1894, and the laboratory studies during the succeeding winters.

The quadrangle studied contains, approximately, 930 square miles and embraces the greater portion of the southern termina-

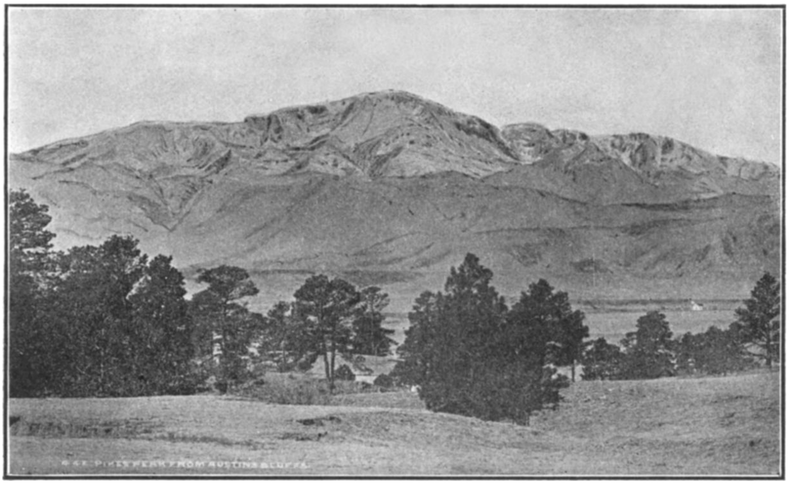

FIG. 1.—Pikes Peak seen from the plain.

tion of the Front or Colorado range in its *en eschelon* ending east of the Royal Gorge of the Arkansas. The topographic features of the area are the mountain massif on the east, rising rapidly as shown in Fig. 1, from the level of the plateau to the height of 14,108 feet above the sea. Westward from the summit the slope is much gentler, as shown in Fig. 2, to the somewhat dissected plateau of Cripple Creek and Florissant, drained on the north by the tributaries of the South Platte River and on the south by Oil Creek and its tributaries which drain into the Arkansas River The divide between these two drainages does not include the summit of Pikes Peak but passes somewhat to the north and west of the mountain mass.

The rocks of the region represent massive and schistose granites, metamorphic schists, remnants of formations belonging to the Algonkian, Cambrian, Silurian, Carboniferous, Jura-trias, Cretaceous, and Eocene periods, and numerous igneous rocks including basic breccias, massive andesite, andesite breccias, trachyte, rhyolite, phonolite, and nepheline-syenite.

The granites and gneisses of the Rocky Mountains have gen-

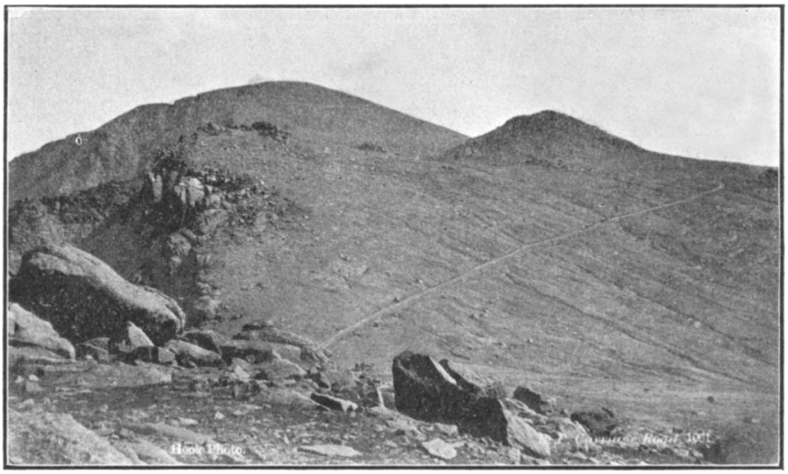

FIG. 2.—Pikes Peak from carriage road (13,000), (showing gentler western slope).

erally been regarded as part of the Archean complex, but it has been shown[1] that within the main granitic masses of the Pikes Peak area there are many included fragments of quartzite and of schists that show their derivation from sandstones through induration and metamorphism. These sediments are regarded as of Algonkian age, and the granites cutting these strata are accordingly either Algonkian or early Cambrian. It is deemed most in harmony with the facts in the case to refer the granitic eruptions to the late Algonkian period.

The schistosity in the gneisses was produced prior to the Upper Cambrian and this fact, together with the assumed age of the granitic eruptions renders it probable that the squeezing

[1] Pikes Peak Folio No. 7, Washington, 1895.

of the granites is due to earth movements which preceded the Cambrian.

The following pages treat almost exclusively of the granitic rocks of the area.

ROCK TYPES

The greater portion of the area studied, as shown by the accompanying sketch and the more complete map in the folio of the Geologic Atlas,[1] is occupied by granites, gneisses, and associated schistose rocks which form an undulating platform underlying the later formations. The prevailing composition of this complex is that of a typical granite with the addition of a small amount of fluorine, while the characteristic mineral constituents remain the same over an area of more than a thousand square miles, notwithstanding the fact that the exposures are representative of bodies intruded at different periods, and crystallized under somewhat different conditions. The granites are light colored, usually pinkish, holocrystalline aggregates of feldspar, quartz and biotite with occasional hornblende and fluorite. The individual components vary in their size and relative abundance and in the perfection of their crystal form ; but in almost every instance the feldspar is larger, more abundant and somewhat better formed than either the quartz or biotite. These variations in the manner of aggregation and in the size of the constituent minerals give rise to well-defined types of granite which were distinguished and plotted in the field.

Although some sixteen varieties of granite were distinguished during the mapping, later study has shown that all masses of prominence may be referred to one of four clearly defined types which have been named,[2] the Pikes Peak, the Summit, the Cripple Creek, and the Fine-grained types respectively.

PIKES PEAK TYPE

A large part of the area of the accompanying map is occupied by a single type of granite, called the Pikes Peak type, from its

[1] Geological sheet. Pikes Peak folio, No. 7, Washington, 1895.

[2] Bull. Geol. Soc. Am., VI, 1894, pp. 471–473.

prominence in the constitution of the Pikes Peak massif. This type is characterized by the relatively large size of its feldspar and quartz grains and its tendency to form conspicuous feldspar phenocrysts that often attain a diameter of several inches.

The fresh, unaltered granites of this type are coarse-grained aggregates of quartz, perthitic feldspars, and biotite with occa-

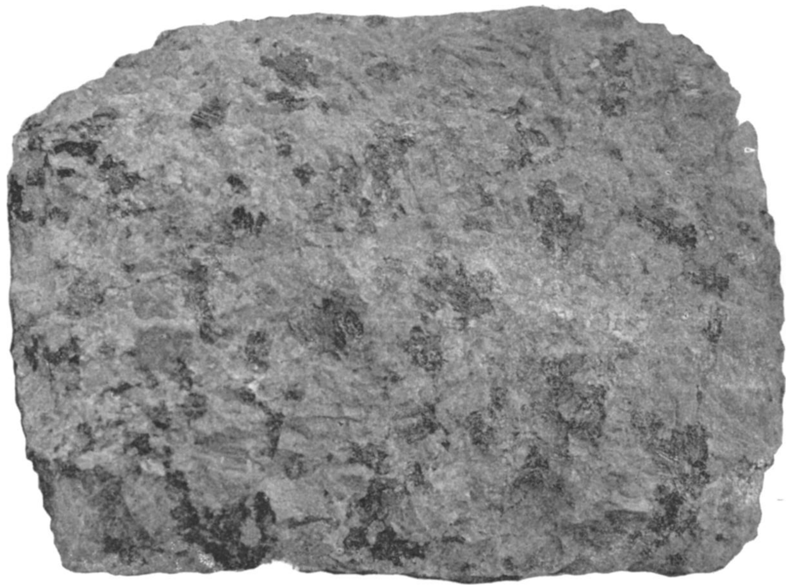

FIG. 3.—Pikes Peak type of the granite.

sional accessory hornblende or fluorite and microscopic apatite, zircon, titanite, magnetite, rutile, hematite, limonite, epidote, and allanite.

The grain varies widely from extremely coarse where the feldspar phenocrysts are six inches long to the more normal granite in which the length of the feldspar grains is little more than a quarter of an inch. The usual diameter for the feldspar is about half an inch, and for the quartz, a quarter of an inch to an eighth of an inch. The biotite areas, although generally smaller than the quartz grains, are sometimes a half inch in width. (Fig. 3.)

The texture of this type presents all grades of transition from that in which the feldspar is only slightly larger than the quartz to one in which the feldspar stands out in large, imperfectly formed porphyritic crystals.[1]

The areal distribution of the rocks showing such increase in the development of the feldspar is not clearly defined, although there is a faint suggestion of a concentric wrapping about the lower slopes of Pikes Peak.

A mechanical separation shows the constituent minerals of the Pikes Peak type to be in the following proportions by weight:

Quartz	33.4
Microcline	53.3
" Biotite "	10.7
Oligoclase	2.6
	100.00

The " biotite " includes all of the minerals with a greater specific gravity than 3.0.

The quartz occurs in large irregular or oval, colorless or smoky grains distinctly outlined against the feldspar and biotite towards which it is usually xenomorphic. In one instance, a basal section of quartz presented three systems of cracks intersecting at 60° representing an imperfect rhombohedral cleavage probably due to mechanical deformation. The extinction ranges from completely simultaneous to mottled or undulatory.

The inclusions observed are arranged according to one of three ways. (1) The small and irregularly shaped inclusions occur either in long thin lines parallel to the rhombohedron, in broader unoriented zones, or irregularly massed in definite parts of the quartz individuals. (2) The small, somewhat rectangular cavities are arranged in indistinct lines parallel to their longer directions but not related to the crystallographic directions of the quartz. (3) The fine, hair-like " needles " have a linear arrangement and seem to occur when the other inclusions are

[1] The coarse-grained granite in which the feldspar phenocrysts are large and generally well formed, is sometimes called the " Raspberry Mountain granite," from its conspicuous development on that mountain.

fewer and more evenly disseminated through the quartz. The mineral nature of the last group could not be determined. The individual inclusions are minute apatites and zircons, hematite plates and magnetite.

Quartz occurs in some of the slides as an inclusion in the feldspars. It is probably secondary in both the microcline and the oligoclase, though in the former it may possibly be original. With the feldspar quartz forms micropegmatitic intergrowths in the more weathered and crushed specimens, but this is lacking in the fresh, unaltered rocks.

The feldspars in the Pikes Peak type vary in size, shape, composition, and age. The color is generally pink or gray, or both where there is a zonal structure. The most important feldspar is microcline perthitically intergrown with albite. This always shows the characteristic "microcline twinning" in all sections inclined to the brachypinacoid. The mesh of the rectangular grating is very small in all those instances which are regarded as original. In the small secondary flakes, however, the mesh is much coarser.

The inclusions within the microcline are albite, quartz, oligoclase, biotite, and the earlier products of crystallization. The most abundant are perthitic pegs of albite, and their disk-like cross-sections. The former lie approximately parallel to a steep positive macrodome in a plane normal to the edge (001) (010). The small round disks may easily be confused with the pellucid quartz from which they can be separated only by the use of converged polarized light.

Oligoclase is only of subordinate importance in the Pikes Peak type where it occurs in small light gray-green anhedral areas with characteristic polysynthetic twinning, lamellae showing on the base an extinction angle of 2°–3°. The inclusions lie close together near the center of the plagioclase plate and are surrounded by a zone of clear feldspar from which they are more or less sharply defined. The cause of the presence and position of these inclusions is not known. The usual explanation based on the increased basicity and consequent instability of the core

may apply, but the same phenomena may be the result of variations in the conditions during solidification. With the less viscous state of the magma during the early stages of solidification the supply of material is abundant and the growth rapid. The imperfections in crystallization increase with the rate of consolidation, through the inclusion of interpositions and the imperfect filling of space. As the magma on cooling becomes more viscous, thereby decreasing the easy transfer of material and the consequent rate of growth, the molecular arrangement of acquired material on the growing crystal is more perfect in its outer zone. This difference in homogeneity between the core and exterior is sufficient to develop a tendency towards molecular rearrangement in the interior whenever the physical conditions are changed. The sharpness of the limits is determined by the growth lines as in twinning lamellae or zonal structures.

Biotite occurs either as individual flakes or small aggregates presenting the appearance of single flakes to the unaided eye. The mica is strongly pleochroic in brown and yellow, and has an optic angle of 10°. Since the plane of the optic axes was found in several instances to lie perpendicular to the leading ray of the percussion figure, much of the mica is probably anomite.

Hornblende is relatively rare in all the granites of the area. It occurs most often in the Pikes Peak type associated with biotite and titanite. The amount of mica decreases somewhat when hornblende is present, while an increase in the latter is generally accompanied by an increase in the titanite. The hornblende-bearing granites occur in somewhat circumscribed areas below Green Mountain Falls, along the railroad east of Florissant and in the hills east of Lake George.

The accessory minerals enumerated on a preceding page occur in varying amounts. They are usually in small crystals, and belong to the earlier stages of consolidation. Titanite and fluorite are of especial interest, since the former has been found only in this type while the latter is rare, though abundant in the Summit type. Neither presents any mineralogical peculiarities.

Among the alteration minerals resulting from the weathering or metamorphism of this type are epidote and sericite associated with the feldspar; and calcite, chlorite, and muscovite accompanying the biotite.

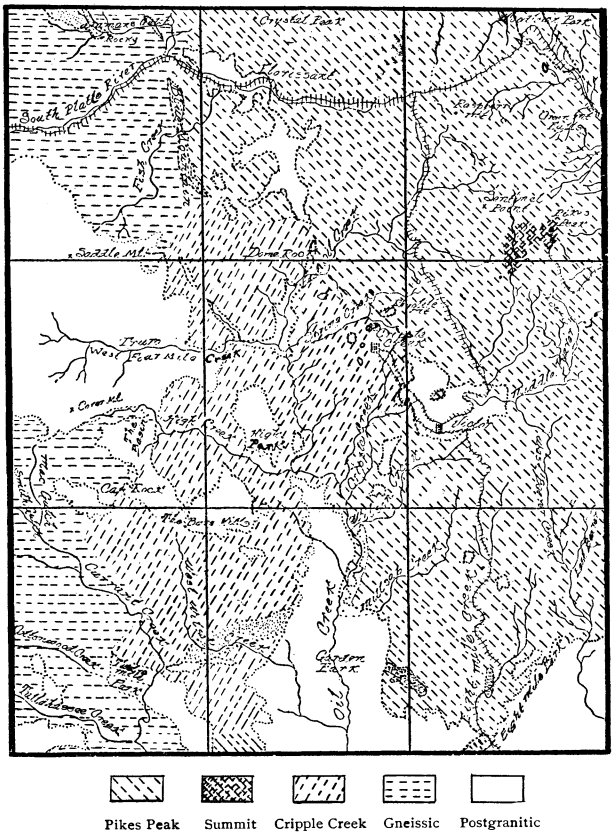

FIG. 4.—Sketch map showing the distribution of the various types of granite occurring in the Pikes Peak quadrangle.

Distribution.—The granites of this type extend northeastward from a sinuous line drawn through the lower slopes of Blue Mountain, Dome Rock, Cripple Creek, and Oil Creek Canyon to the southeastern border of the Pikes Peak Quadrangle. (Fig. 4) The limits beyond the area of the Quadrangle have not been

examined, but are shown in a general way in the maps of the early Hayden survey some miles to the north and east of the Pikes Peak area. Similar rocks have been described from the Platte Canyon in Jefferson county for the Educational Series of the United States Geological Survey.[1]

In its distribution the Pikes Peak type, in the contact with each of the three remaining types distinguished, appears as the older type. It is therefore the oldest granite in the area. The best place for studying the age of this type is in the region about the summit of the massif. Here it is cut by many dikes of the Summit type, which seem to radiate from the central eminence. The actual contact between the two granites is rarely evident in this area, however, as the blocks of the Summit type have formed a slide slope which masks the more easily disintegrating coarse-grained granite. Wherever the contact is observable, as in Wilson Creek southeast of Cripple Creek, the finer rock is seen to cut the coarser. The relations with the Cripple Creek type are poorly defined, as the exposures almost always show small masses of metamorphosed sediments at the immediate contact. The greater age of the Pikes Peak type is shown, however, in several exposures, as, for example, on the north side of Caylor Gulch at an elevation of 8600 feet, where a fine-grained saccharoidal granite of the Cripple Creek type cuts the coarser schistose granite which is correlated with that of the Pikes Peak type.

Weathering.—The processes and results of weathering in the Pikes Peak type are among its most characteristic features. The light pink color becomes darker on exposure and passes into a deep red through a bleaching of the biotite and the subsequent staining of the feldspars and quartz with the liberated iron oxide. The physical changes due to weathering are, however, more manifest. The rock disintegrates before it is decomposed. For this reason the hills are rounded and covered with granite gravel when the disintegrated material remains, and rugged or steep where the débris has been carried away. Fig. 2 gives a view of

[1] Bull. U. S. Geol. Surv., No. 150, Washington, 1898, pp. 172–177.

Pikes Peak from the northwest at an elevation of 13,000 feet, which well illustrates this difference. On the west the mountain slopes with smooth rounded outline into the drainage of Beaver Creek, while on the east the descent is precipitous in ragged cliffs, sometimes resembling huge cyclopean masonry. Counteracting this physical disintegration are chemical changes which

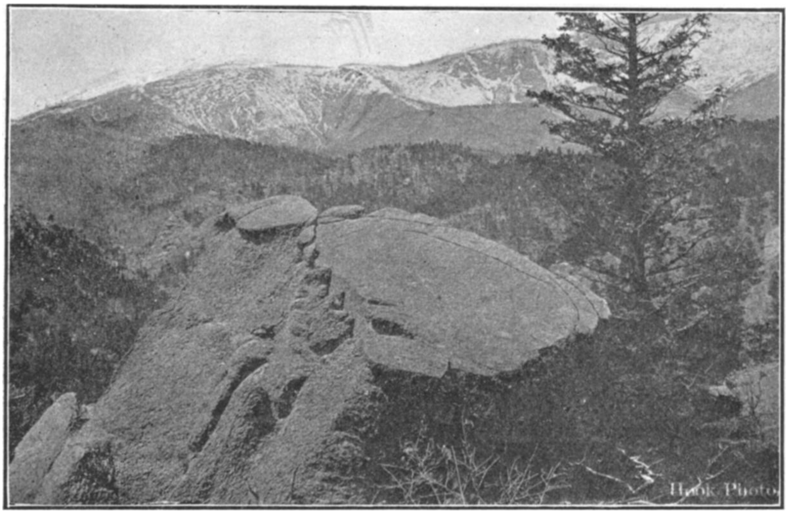

FIG. 5.—Disintegrated bowlder of granite showing surface hardening and disintegration beneath.

protect the rock at first, but ultimately, in conjunction with the physical forces, accelerate the rate of rock-weathering.

The effect of weathering extends for a distance of two or three feet beneath the surface of the exposed rocks. On the exterior there is fréquently a dense crust, or glazing, rarely more than half an inch thick, covering a second zone several inches wide, in which the mineral are stained with iron and loosely held together. Beneath this zone the rock is often so incoherent that it seems ready to fall to pieces. The crumbling mass, in turn, passes gradually into the solid rock. Fig. 5 represents a bowlder with the coating on the surface and the disintegrating rock beneath. In this view the upper surface appears

more resistant to the weathering agencies, while the friable rock beneath has fallen away leaving the crust as a projecting edge. Such a crusting over friable material often leads to fantastic shapes, as represented in Fig. 6. The final result of the weathering is the formation of a thick coating of talus and granite gravel, composed of relatively fresh fragments of the rock and its mineral constituents.

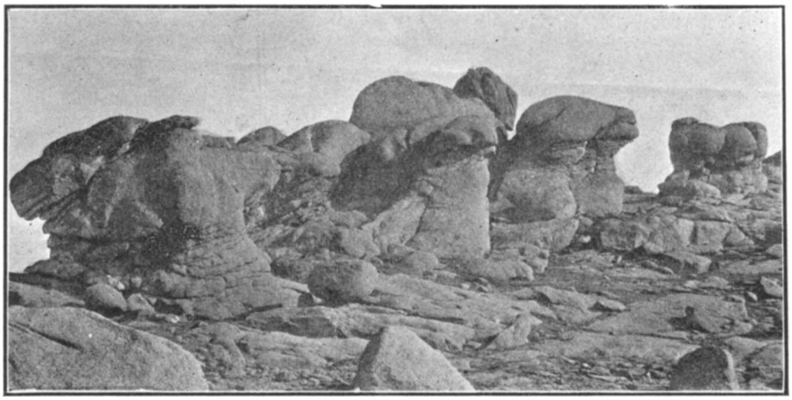

FIG. 6.—Fantastic forms due to weathering and surface hardening.

SUMMIT TYPE

The rocks of the Summit type show a very constant texture closely allied to that of granite-porphyry (Fig. 7). They are composed essentially of small gray feldspar phenocrysts embedded in a finely granular aggregate of hypidiomorphic, quartz, smaller feldspars, biotites, and minute grains of fluorite. Microscopic zircon, magnetite, hematite, and micropegmatitic intergrowths of quartz and feldspar are also present.

When fresh the color of the rock is purple, ranging from purple-violet to carmine-purple.[1] As the rock becomes weathered the color becomes less pronounced and fades to light neutral gray and brown.

The minerals composing the Summit type differ very slightly from those described under the preceding type. Quartz is more

[1] Nos. 23_p and 26_s of Radde's International Farben scala.

abundant and in smaller areas, and the numerous fine grains in the groundmass are free from much included matter. The larger individuals, however, present the broad zones of inclusions noticed in the preceding type. The porphyritic feldspar is microcline, as in the first type, but here the perthitic intergrowths of albite are much less common. The microcline also

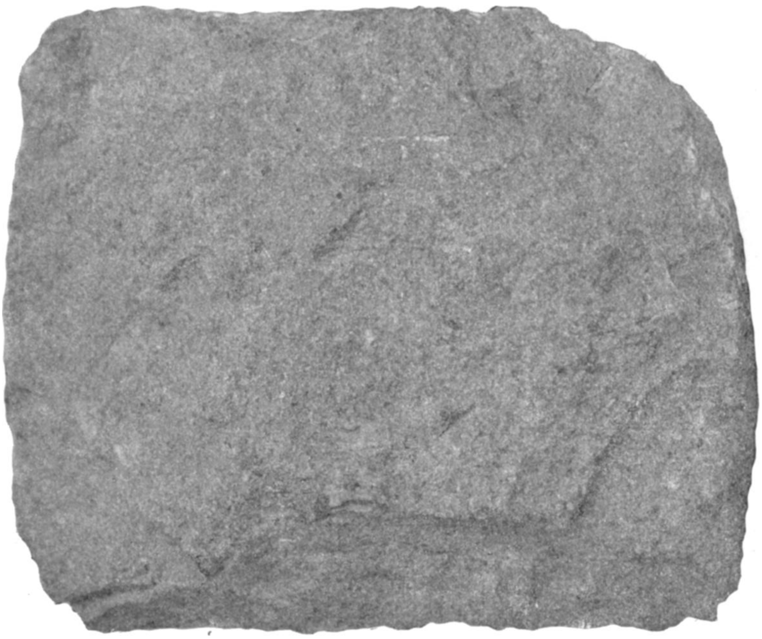

FIG. 7.—Summit type fine grained granite-porphyry.

composes much of the groundmass where it fills the interstices between the grains of quartz. Untwinned clear grains of feldspar, probably orthoclase, are also present in the groundmass in considerable abundance. Oligoclase showing fine twinning lamellae is more poorly developed than in the Pikes Peak type. All of the feldspars are much clouded with alteration products, especially by sericite and some iron compound, either hematite or limonite. The abundant development of micropegmatitic intergrowths of quartz and microcline in this type is noteworthy, as these are practically wanting in the fresh Pikes Peak granite. The

quartz occurs in small oval, or irregular, disks which have the same orientation over considerable areas of the feldspar. Although these disks may lengthen out, they do not have the branching-radial arrangement characteristic of some of the other occurrences.

The biotite occurs in flakes without good crystal outline, and locally shows quite an advanced stage in the alteration towards chlorite and lenses of quartz formed between the foliae. The same slide may show perfectly fresh pieces of biotite associated with that which has become thoroughly chloritized. Unlike the mica of the Pikes Peak granite, the biotite of the Summit type is of the first order with the plane of the optic axes parallel to the principal ray of the percussion figure.

Hornblende, titanite, and magnetite are practically wanting in this type, although a few fresh irregular grains of the latter were noticed in a single slide.

The most characteristic mineral in the Summit type is fluorite. This is present in every section but one made from the Summit granites. It is commonly in small irregular areas and rarely in well-defined crystals. When the crystal contours are evident the little squares suggest either cubes or octahedrons. The mineral is especially characterized by a highly perfect octahedral cleavage which is well developed in the larger areas, but is lacking in the minute crystals. The anhedral areas are clear and either colorless, purple, faintly pink, or green. The pigment is unevenly disseminated through the grains, and seems to be more intense about inclusions than in the clearer parts of the mineral. Between crossed nicols the areas remain perfectly isotropic, and in ordinary light the mineral shows a shagreened surface corresponding to its very low index of refraction. All of the properties enumerated are characteristic of fluorite. The view that this is fluorite is corroborated by the high percentage of fluorine in the bulk analyses and the presence of fluorides in the veins of adjacent areas.[1] Microchemical tests were made, but failed to give conclusive results.

[1] E. g., St. Peter's Dome (Bull. U. S. Geol. Surv., No. 20), and Cripple Creek (Sixteenth Ann. Rept. U. S. Geol. Surv., II, 1895).

Although the gold ores and the fluorite are sometimes intimately associated in the mining area near Cripple Creek, no indications of gold, sulphides, or tellurides were seen in any of the sections of the Summit type.

Distribution.—The rocks of the Summit type are confined to a small area about the Summit and down the western slope of the highest part of Pikes Peak, and the relation between them and the other granites is only seen in a few places. On the main peak there seems to be a system of radiating dikes, but the contacts are not well exposed in place. In Wilson Creek canyon and near the intersection of Spring Creek with the Cripple Creek-Florissant road there are dikes of granites correlated with that of the Summit type which clearly cut the older Pikes Peak granite.

Towards the other granites this type seems to be older, since it is never found in them, while they occur in small masses within its areas.

Weathering.—In the manner of their weathering the rocks of the Summit type show many differences from those of the Pikes Peak type. Instead of disintegrating into massive, rounded bowlders and coarse gravels like the latter, the granite-porphyry breaks up into smaller angular blocks, as illustrated in the familiar views of the Upper Station of the Pikes Peak Railway. These blocks and many of the ledge exposures, moreover, have a glazed crust similar to that observed on bowlders of the Pikes Peak type. What the nature of the process is which produces this surface was not determined in the somewhat hasty survey of the upper portions of the mountain, although the natural surroundings suggest three possible agencies for such polishing, viz., blown sand, ice, and chemical action. The smoothness of the surfaces and the occurrence of polished surfaces in sheltered hollows is against any polishing by sand, while the presence of a crust on somewhat recently formed bowlders and steep slopes, and the absence of glacial striae militate against any explanation based on ice action. The thickness of the shell and the decayed character of the interior, on the other hand, seem to indicate that

this crust is due to chemical action. The great diurnal changes in temperature, the dryness of the air, and the direct action of the sun tend to promote rapid changes in the amount of moisture present, and this in turn would cause alternations of solution and precipitation. Throughout the nights and the winter seasons the rocks receive by capillary action a considerable supply of moisture which during the day and the summer would take some of the material from the interior and carry it to the surface, where there would be rapid evaporation and precipitation. Such action must be slow, as the material carried out is but slightly soluble even under favorable conditions; and yet this very insolubility helps in the final result by rendering at least a portion of the deposited material independent of the rains. The increased amount of silica in the crust seems to corroborate this hypothesis of chemical action.[1] The formation of a crust on the rhomboidal joint blocks, together with the closeness of grain of the rock accounts in great measure for the angularity of the blocks strewn over the summit, and may in part account for the present topographic preëminence of this portion of the massif.

CRIPPLE CREEK TYPE

The granites grouped under this title, compared with those of the preceding types, appear finer than those of the Pikes Peak type and more evenly grained than those of the Summit type. They are finely coherent saccharoidal aggregates of microcline, vitreous quartz, and glistening biotite with occasional microscopic individuals of zircon, hematite, magnetite, and apatite. When phenocrysts are present they are usually microcline, although in an exposure at the Placer Mill northwest of Cripple Creek, broad glistening flakes of biotite are porphyritically developed.

The most prominent constituents are small, rectangular crystals of fresh pink microcline which occasionally reach the length of half an inch (Fig. 8). The twinning network is medium coarse

[1] CROSBY (Merrill, Rock Weathering, p. 255) suggests also the deposition of iron oxide.

and therefore differs from that of the other types. This mesh, however, is not as coarse as that in the smaller, probably secondary, microclines present in the same slides, and in the altered granites more fully described elsewhere. Perthitic intergrowths with albite are not prominent in the majority of the sections, but are very abundant in the slides representing some of the

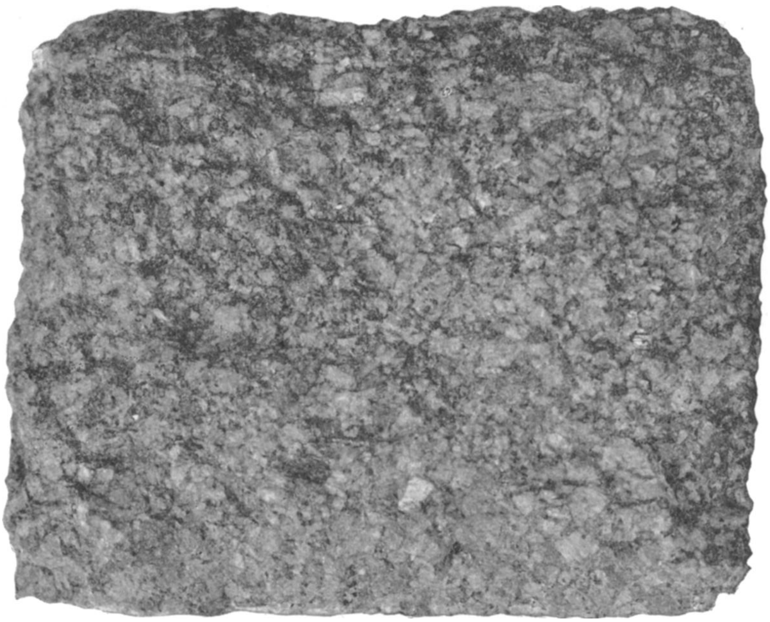

FIG. 8.—Cripple Creek type of the granite.

granites from the vicinity of Seven Lakes. The microclines of this locality are twinned parallel to the basal pinacoid, according to the Manebach law, and differ only in size and occurrence from the large and beautiful amazonstone and orthoclase so well known from this area. The perthitic lamellae meeting at the composition face (001) form an angle of 147° and in each case lie a few degrees from the vertical axis in obtuse β (parallel to a steep positive orthodome).[1]

[1] In color and texture this rock resembles the well-known granite from Red Beach, Me., described in the Tenth Census, and it is probable that if similar rock can be found where the conditions of quarrying and transportation are favorable it will prove of economic interest.

The irregularly oval grains of quartz composing from one seventh to one quarter of the rock-mass are either clear and vitreous, as in the granites from Seven Lakes, or small and stained with iron, as in the rocks collected in Caylor Gulch They are somewhat poor in fluid inclusions but show a great number of fine "quartz-needles." The iron-staining occurs as a filling in the cracks, rather than as a minutely disseminated pigment or fine evenly distributed hematite flakes.

Like the granites of the Pikes Peak type, those of the Cripple Creek type do not have very much micropegmatite developed in the fresh specimens, and when it is developed the quartz does not show the arborescent and radiate growths so abundant in the weathered and metamorphosed rocks, but is present in small rounded disks or ovals similar to those described by Romberg.[1]

The plagioclase occurs in small anhedral grains which are older than the quartz and the microcline. They are generally clouded with alteration products which may be either irregularly distributed through the individual; arranged parallel to the twinning lamellae; or concentrated in the center with a surrounding clear zone in similar optical orientation. The twinning lamellae, according to the albite law, are very fine and usually extinguish almost simultaneously parallel to their composition face.

The other constituents, zircon, apatite, and magnetite, show no unusual features and are very sparingly developed.

Distribution.—The granites of the Cripple Creek type are most characteristically developed in the area lying to the west of a line drawn from Lake George to the town of Cripple Creek and thence in a somewhat sinuous line to the waters of Oil Creek. Between this line and the volcanic deposits on the west is a broad stretch of relatively level country considerably dissected on its eastern side by Oil Creek and its tributaries.

The contacts against the Pikes Peak type are generally obscured by the presence of narrow bands of highly metamorphosed schists which were included in the older type and cut by

[1] N. J. B. B-B. VIII, 1892.

the granites of the Cripple Creek type in a manner well shown near the mouth of Arequa Gulch a few miles below the town of Cripple Creek. On the west the contacts with the gneissic granite are generally obscure, though the finer grained may be seen cutting the coarser and more schistose rock in Caylor Gulch at an elevation of 8600 feet.

The manner of weathering and the resulting physiographic forms are intermediate between those of the Pikes Peak and Summit types. The hills are neither so smooth, so bold, nor so massively jointed as those composed of Pikes Peak granite; while the disintegrated fragments are not as compact and angular as those of the Summit type. The mineralogical changes are those common to granitic minerals.

FINE GRAINED TYPE

The rocks included under this head do not occur in well-defined masses extending over large areas but in small dikes distributed throughout the entire area studied. Nor are they so closely allied in their mineralogical and textural features as members of the preceding three groups. Their correlation is based upon their composition and texture, mode of occurrence, age, and present topographic position rather than upon their areal continuity. All of these rocks are fine grained hypidiomorphic granular aggregates of reddish color, composed of quartz, feldspar, and one or both kinds of mica, with small amounts of microscopic fluorite, magnetite, epidote, zircon, and apatite.

The color of these rocks varies from brilliant red to pinkish-white or dull yellow, but is usually bright pink. In the latter case the feldspars are stained by finely disseminated iron oxide. The size of the individual grains is very constant, and rarely exceeds one sixteenth of an inch. Among the individual constituents there are several points of difference from the same minerals in the earlier types. Quartz is more abundant and in grains as large or larger than those of microcline, while incipient granulation shown by a mottled extinction is more frequent.

Among the feldspars, microcline shows a slight increase in the size of its twinning network and the plagioclase a decrease in the size and abundance of its grains. Perthitic intergrowths are practically wanting in these rocks, whether fresh or altered, while micropegmatitic intergrowths are abundant, especially in the slides where the evidences of mechanical deformation are

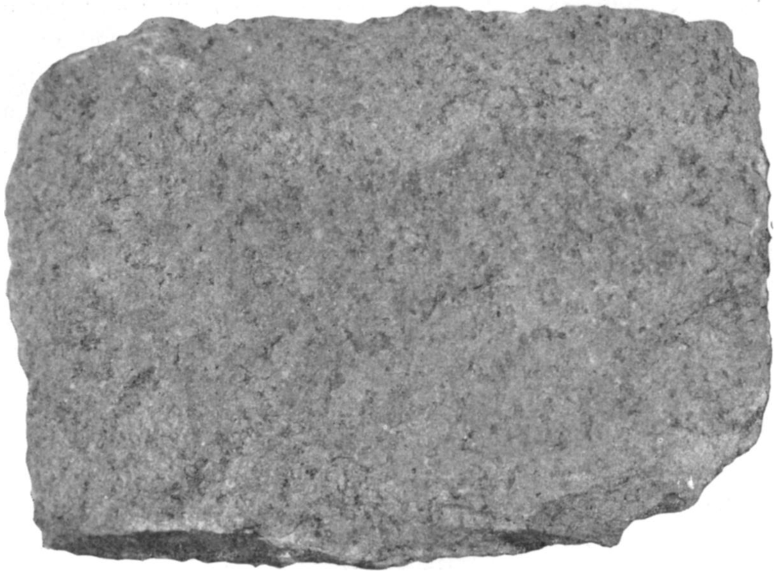

FIG. 9.—Fine grained type of granite.

most numerous. The micas show no unusual features beyond the occasional inclusion of tiny individuals of fluorite showing well-defined crystal outlines in fresh flakes of biotite.

Weathering.—The effect of atmospheric action on the fine-grained granites varies somewhat, but is ordinarily less pronounced than that on the other three types. When the rock disintegrates it usually falls into a mass of angular bowlders of small size, which are quite compact and sometimes covered with a surface glaze. This coating, which is faintly shown in Fig. 9, is much less clearly defined than is that on the Pikes Peak or

Summit types, and it does not appear to be as commonly developed. Ledge exposures of this type are comparatively rare, as the solid rock is usually covered by angular bowlders. The relatively greater resistance to weathering, due probably to the more compact texture of the rock, is clearly brought out in the topographic position of its exposures. When the fine-grained granite occurs in any considerable mass it forms the tops of minor hills and ridges. This is well shown in many places within the area of the map, the best illustration occurring on the subordinate ridges of the slopes of Pikes Peak and in the rugged area between Grouse Hill and Red Mountain, on the sides of the canyon of Cripple Creek.

TABLES SHOWING THE COMPARATIVE ABUNDANCE AND SIZE OF THE CONSTITUENTS OF THE DIFFERENT TYPES

The comparative abundance, size, and development of the various constituents in the four types of granite described in the preceding pages, are summarized in the following tables:

TABLE I. SHOWING RELATIVE ABUNDANCE OF MINERALS

	Pikes Peak	Summit	Cripple Creek	Fine grained
Quartz	abundant	abundant	abundant	predominant
Microcline	predominant	predominant	predominant	predominant
Orthoclase		fairly commonly		
Oligoclase	constant	constant	constant	constant
Perthitic intergrowths	well developed	unusual	not marked	
Micropegmatite	very rare	very abundant	rare	present
Hornblende	present			
Biotite	abundant	abundant	present	present
Muscovite				common
Fluorite	rare	very marked		present
Apatite	constant	rare	rare	present
Zircon	constant	present	constant	constant
Titanite	present			
Epidote	rare			present
Magnetite	present	rare	present	present
Hematite	present		present	present

TABLE II. SHOWING RELATIVE SIZE AND DEVELOPMENT

	Pikes Peak	Summit	Cripple Creek	Fine grained
Quartz				
Size	$3-10^{mm}$ 5^{mm} average	$2-4^{mm}$	$3-5^{mm}$	$1-3^{mm}$
Form	irregular	spheroidal	irregular	irregular
Microline	(Phenocrysts)			
Size	$6'' \times 3''$ to 15×30^{mm}, 20×30^{mm} as	25×15 to 4×7^{mm}	7×5^{mm}	
Form	well developed	well developed	well developed	
Microline	(Groundmass)			
Size	10×15^{mm}	$2. \times .05^{mm}$	1×3^{mm}	1×2^{mm}
Form	irregular	irregular	irregular	irregular
Biotite				
Size	$3-4^{mm}$	$1-2^{mm}$	1^{mm}	$0.5-1^{mm}$
Mode of aggregation..........	single and aggregate	single and aggregate	single and aggregate	single or aggregate
Texture				
Coarseness ...	coarse	Medium to fine	medium	fine
Arrangement ...	granular to porph. gran.	granitophyric	saccheroidal to orthophyric(?)	granular
Mode of occurrence	large masses	small masses and dikes	large masses	small masses and dikes

The accompanying tables show at a glance the marked similarity in the mineralogical composition, and the equally marked diversity in the textural relations presented by the different types. The diversity in the mineralogical composition of the different types is no more than that due to the presence of occasional orthoclase, hornblende, sphene, muscovite, or epidote in specimens collected over an area of more than nine hundred square miles. These types, it is true, show well developed perthitic intergrowths to be common in the fresh granites of the Pikes Peak type and wanting in the other types ; while fluorite and micropegmatite are prominent in the rocks of the Summit type and unusual in the rest of the unaltered granites. The most striking, most constant, and most characteristic differences between the types are, however, in the relative and absolute size

of the constituents, and not in the specific character of the minerals present.

The second table shows a variation in the size of the quartz constituent from grains averaging 5^{mm} in diameter in the Pikes Peak type to those of $\frac{1}{3}^{mm}$ in the fine grained granite. A similar variation is noticeable in the mica, from flakes of $0.5-1^{mm}$ in the fine grained type to those of $3-4^{mm}$ in the Pikes Peak type. The microclines also show a similar change in the same direction, whether they are phenocrysts or not; and in addition the fine-grained granites show no feldspars porphyritically developed. This uniform change in the size of the constituents can only result in the production of a similar variation in the coarseness of grain, as shown in the tables.

Table I, together with the chemical composition of the rocks, brings out the similarity or family likeness existing between the different granites; a likeness that signifies their origin from a common magma relatively rich in silica and fluorine. Table II, with the field relations, substantiates this view and explains the many local differences shown in texture, or mode of aggregation, of the different constituents. The coarse-grained Pikes Peak and Cripple Creek granites formed large masses, while the Summit and fine grained rocks occur in physical conditions sufficiently variable to account for the variations in texture which distinguish the rocks of these types.

CHEMICAL COMPOSITION

The marked uniformity in the mineralogical composition of the various granites from all portions of the area suggests a similar uniformity in the chemical composition. The abundance of quartz and perthitic microcline, with the small amounts of plagioclase, mica, and accessory minerals, indicate a relatively high percentage of silica and the alkalis, with a comparatively small amount of calcium, iron, and magnesium. The presence of fluorite, also, suggests the actually small, but relatively high, percentage of the unusual constituent fluorine. These inferences from the mineralogical composition are fully sustained by the

following complete and careful analyses made by Mr. W. F. Hillebrand of the U. S. Geological Survey.

TABLE OF CHEMICAL ANALYSES

	I (2128)	II (2531)	III (2530)	IV (2369)	V
SiO_2	77.03 1.284	75.17 1.253	73.51 1.225	73.90 1.221	74.90 1.248
TiO_2	.13 .001	.10 .001	.18 .002	.07 .000	.12 .001
Al_2O_3	12.00 .116	12.66 .122	13.28 .129	13.65 .132	12.89 .125
Fe_2O_3	.76 .004	.23 .001	.94 .006	.28 .001	.58 .003
FeO	.86 .012	1.40 .019	.97 .013	.42 .005	.91 .012
MnO	tr.	tr.	tr.	tr.	......
CaO	.80 .014	.83 .014	1.11 .020	.23 .004	.74 .013
SnO	......	tr. ?	......	......	......
BaO	tr.	.03	tr.	tr.	......
MgO	.04 .001	.05 .01	.05 .001	.14 .003	.07 .001
K_2O	4.92 .052	5.75 .061	5.22 .055	7.99 .085	5.92 .063
Na_2O	3.21 .051	2.88 .046	3.79 .061	2.53 .040	3.10 .050
Li_2O	tr.	st. tr.	tr.	tr.	......
H_2O*	.14	.16	.16	.15	.15
H_2O†	.30	.62	.31	.92	.55
P_2O_5	tr.	.03	tr.	.05	.02
Fl	.36	.31	.55	......	.31
CO_2	......	......	......	......	......
	100.55	100.26	100.38	99.75	......
O less F	.15	.13	.22	......	......
	100.40	100.13	100.16	99.75	100.26

* Below 110° C. † Above 110° C.

I. (2128.) A coarse grained granite of the Pikes Peak type taken from the western side of the Pikes Peak massif at a place

called Sentinel Point (12,300 feet). Feldspar is the most important constituent, with quartz very abundant in somewhat smaller grains. The mica occurs in both single individuals and in aggregates of minute flakes. A thin section of this rock is composed, almost entirely, of quartz and microcline, the latter showing a few lamellae of perthitic plagioclase.

II. (2531.) A porphyritic granite of the Summit type collected from the divide tunnelled by the Colorado Springs Water-works (elevation about 12,000 feet). This is composed of feldspars and large grains of quartz in a fine grained, reddish to purplish groundmass.

III. (2430.) A fine grained variant of the Summit type collected on the head waters of the Middle Beaver, nearly opposite the Bear Creek road to the Colorado Springs Water-works. The prominence of the biotite against a fine grained groundmass of feldspar, and the peculiar purplish hue due to the disseminated fluorite, are the chief characteristics.

IV. (2369.) A fine grained granite of the fourth type taken from Smith's Gulch not far from Current Creek P. O. This is composed of quartz and microcline with small amounts of mica.

V. An average of the preceding.

The following conclusions based on a comparative study of the analyses seem to be warranted by the figures. When the individual analyses and their average are reduced to molecular proportions and compared with an average of twelve type analyses given by Zirkel[1] and several analyses given by Rosenbuch[2] similarly reckoned, it is seen that they all are richer in silica than the averages given in the text-books, though not richer than individual specimens from many areas. The sum of the alkalis seems to conform to that of the averages but the granites of the Pikes Peak area are relatively richer in potassium. This relation between the alkalis becomes of additional interest when the occurrence of nepheline-bearing rocks near Cripple Creek is considered.

[1] Lehrbuch der Petrographie, 2te. Aufl. II, p. 29.

[2] Elemente der Gesteinslehre, p. 186.

Among the elements represented, fluorine is of the most interest. Although small in amount the still smaller quantities of lime and phosphorus show that there is enough present to satisfy all of the latter even in the form of pure fluor-apatite, and much of the former in the form of fluorite. The possible excess of calcium is so small that the plagioclase plates must be sodium rich oligoclase and the perthitic pegs albite.

The low percentage of iron and magnesium together with the strong pleochroism of the mica explains the relative scarcity of this mineral.

The chemical analyses confirm the microscopic determinations and show that the general magma was of such a composition as might produce a rock composed essentially of a potassium feldspar, perhaps intergrown with albite, and considerable quartz, with small amounts of fluorite and iron rich mica.

RÉSUMÉ

The area included within the Pikes Peak quadrangle is a complex of granites, gneisses and schists overlain by numerous sedimentary and volcanic rocks of later age. The unaltered granites show, over an area of more than a thousand square miles, a notable uniformity in their mineralogical and chemical composition which is marked by the persistent presence of holocrystalline quartz-microcline aggregates bearing small amounts of equally constant biotite. On the other hand, these same rocks show a distinct diversity in the abundance, size, and form of their constituent minerals and the consequent differences in texture.

The variations in texture and composition are as follows:

Pikes Peak type.—Coarse granular to coarse porphyritic: rich in perthitic feldspar, poor in micropegmatitic intergrowths, and fluorite with occasional hornblende and titantite.

Summit type.—Granitophyric; poor in perthitic feldspars but rich in micropegmatite and fluorite.

Cripple Creek type.—Saccharoidal with rectangular feldspars; poor in perthitic feldspars, micropegmatite, and fluorite.

Fine grained type.—Fine granular; poor in perthitic feldspar, micropegmatite, and fluorite but bearing some muscovite.

Emphasis has often been laid on the variations in the chemical or mineralogical composition of masses showing uniformity in their texture. The present instance represents on a large scale the opposite changes. Here there are well-defined differences in texture in a mass of uniform chemical composition. The changes in mineralogical composition are slight, and represent little or no difference in the chemical proportions of the mass except in the case of the fluorite. The other changes are local and partake of the nature of "dark patches."

Besides these original differences in the textures there are others of secondary origin where the feldspar phenocrysts have become lenticular "eyes" and the massive granites have been changed to granite-gneisses.

EDWARD B. MATHEWS.